is about an inch in length, and a quarter of an inch across the instep, from which it tapers elliptically to a pointed toe, while the heel at the anterior extremity is abruptly truncated and broadly notched.

The slipper is ornamented with eight principal spiny ridges, taking a longitudinal direction, diverging from the toe and terminating separately at the heel. But the central vertical ridge corresponding with the front of the slipper is cut off where a square notch or fissure in the instep receives the muscular attachment of the animal. The whole scheme of arrangement will be better understood on inspecting the accompanying figure, which is about three times the natural size.

III. "On the Agency of Water in Volcanic Eruptions; with some Observations on the Thickness of the Earth's Crust from a Geological Point of View; and on the Primary Cause of Volcanic Action." By JOSEPH PRESTWICH, F.R.S., Professor of Geology in the University of Oxford. Received March 26, 1885.

(Abstract.)

That water plays an important part in volcanic eruptions is a well-established fact, but there is a difference of opinion as to whether it should be regarded as a primary or a secondary agent, and as to the time, place, and mode of its intervention. The author gives the opinions of Daubeny, Poulett-Scrope, and Mallet, and dismissing the first and last as not meeting the views of geologists, proceeds to examine the grounds of Scrope's hypothesis — the one generally accepted in this country—which holds that the rise of lava in a volcanic vent is occasioned by the expansion of volumes of high pressure steam generated in the interior of a mass of liquefied and heated mineral matter within or beneath the eruptive orifice, or that volcanic eruptions are to be attributed to the escape of high pressure steam existing in the interior of the earth. The way in which the water is introduced and where, is not explained, but as the expulsion of the lava is considered to be due to the force of the imprisoned vapour, it is, of course, necessary that it should extend to the very base of the volcanic foci, just as it is necessary that the powder must be in the breech of the gun to effect the expulsion of the ball.

The author then proceeds to state his objections to this hypothesis. In the first place, he questions whether it is possible for water to penetrate to a heated or molten magma underlying the solid crust. The stratigraphical difficulties are not insurmountable, although it is well known that the quantity of water within the depths actually

reached in mines, decreases, as a rule, with the depth, and is less in the Palæozoic than in the Mesozoic and Kainozoic strata.

The main difficulty is thermo-dynamical. As the elastic vapour of water increases with the rise of temperature, and faster at high than at low temperatures, the pressure,—which at a depth of about 7,500 feet and with a temperature (taking the thermometric gradient at 48 feet per 1° F.) of 212° F., would be equal to that of one atmosphere only,—would at a depth of 15,000 feet and a temperature of 362°, be equal to $10\frac{1}{2}$ atmospheres, and at 20,000 feet and temperature of 467°, would exceed 25 atmospheres. Beyond this temperature the pressure has only been determined by empirical formulæ, which, as the increase of pressure is nearly proportional to the fifth power of the excess of temperature, would show that the pressure, in presence of the heat at greater depths, becomes excessive. Thus, if the formulæ hold good to the critical point of water or 773°, there would at that temperature be a pressure of about 350 atmospheres.

At temperatures exceeding 1000° F. and depth of about 50,000 feet, the experiments of M. H. St. Claire Deville have shown that the vapour of water, under certain conditions, probably undergoes dissociation, and, consequently, a large increase in volume. It would follow also on this that if the water-vapour had been subject to the long-continued action of the high temperatures of great depths, we might expect to meet with a less amount of steam and a larger proportion of its constituent gases than occurs in the eruptions. Capillarity will assist the descent, and pressure will cause the water to retain its fluidity to considerable depths, but with the increasing heat, capillarity loses its power.

Taking these various conditions into consideration, the author doubts whether the surface waters can penetrate to depths of more than seven to eight miles, and feels it impossible to accept any hypothesis based upon an assumed percolation to unlimited depths. That there should be open fissures through which water could penetrate to the volcanic foci, he also considers an impossibility.

But the objection to which the author attaches most weight against the extravasation of the lava being due to the presence of vapour in the volcanic foci, is, that if such were the case, there should be a distinct relation between the discharge of the lava and of the vapour, whereas the result of an examination of a number of well-recorded eruptions, shows that the two operations are in no relation and are perfectly independent. Sometimes there has been a large discharge of lava and little or no escape of steam, and at other times there have been paroxysmal explosive eruptions with little discharge of lava.

There are instances in which the lava of Vesuvius has welled out almost with the tranquillity of a water-spring. A great eruption of Etna commenced with violent explosions and ejection of scoriæ,

which after sixteen days ceased, but the flow of lava continued for four months without further explosions. In the eruption of Santorin of 1866, the rock-emission proceeded for days in silence, the protruded mass of lava forming a hill nearly 500 feet long by 200 feet high, which a witness compared with the steady and uninterrupted growth of a soap bubble. The eruptions of Mauna Loa are remarkable for their magnitude and at the same time for their quiet. Speaking of the eruptions of 1855, Dana says there was no earthquake, no internal thunderings, and no premonitions. A vent or fissure was formed, from which a vast body of liquid lava flowed rapidly but quietly, and without steam explosions, for the space of many months.

On the other hand, paroxysmal eruptions are generally accompanied by earthquakes, and begin with one powerful burst, followed rapidly by a succession of explosions, and commonly with little extrusion of lava, although it is to be observed that a large quantity must be blown into scoriæ and lost in the ejections. Such was the eruption of Coseguina in 1835, and of Krakatoa in 1883. Sometimes in these paroxysmal eruptions, there is absolutely no escape of lava, scoriæ alone being projected. A common feature in eruptions, and which indicates the termination of the crisis, is the stopping of the lava, though the gaseous explosions continue for some time with scarcely diminished energy.

There is, thus, no definite relation between the quantity of explosive gases and vapours and the quantity of lava. If the eruption of lava depended on the occluded vapour, it is not easy to see how there could be great flows without a large escape of vapour, or large volumes of vapour without lava. The extrusion of lava has been compared to the boiling over of a viscid substance in a vessel, but the cases are not analogous.

The only logical way in which it would seem possible for water to be present, is on the hypothesis of Sterry Hunt, who supposes the molten magma to be a re-melted mass of the earlier sedimentary strata, which had been originally subject to surface and meteoric action. But in the end the preceding objections apply equally to this view.

There is the further general objection to the presence of water in the molten magma, in that were the extrusion of lava due to this cause, the extrusion of granite and other molten rocks (which do not as a rule lie so deep as the lava magma) should have been the first to feel its influence and to show its presence. Yet although water is present, it is in such small quantities, that these rocks never exhibit the scoriaceous character which lava so commonly possesses.

Nor is lava always scoriaceous, as it should be if the hypothesis were correct. Many lavas are perfectly compact and free from vapour

cavities, and so also are especially most of the great sheets of lava (basalt), which welled out through fissures in late geological times. These vast fissure eruptions, which in India and America cover thousands of square miles, and are several thousand feet thick, seem conclusive against water agency, for they have welled out evidently in a state of great fluidity, with extremely little explosive accompaniments, and often without a trace of scoriæ mounds. The general presence of non-hydrated rocks and minerals is also incompatible with the permeation of water which the assumption involves.

It has been suggested by some writers that large subterranean cavities may exist at depths in which the vapour of water is stored under high pressure, but the author shows that such natural cavities are highly improbable in any rocks, and impossible in calcareous strata.

The author proceeds to account for the presence of the enormous quantity of the vapour of water, so constantly present in eruptions, and which, in one eruption of Etna, was estimated by Fouqué to be equal to about 5,000,000 gallons in the twenty-four hours. He refers it to the surface-waters gaining access *during the eruptions* to the volcanic ducts either in the volcanic mountain itself, or at comparatively moderate depths beneath. He describes how the springs and wells are influenced by volcanic outbursts. By some observers, these effects have been referred to the influence of dry and wet seasons, but there are so many recorded instances by competent witnesses, as to leave little doubt of the fact. This was also the decision of the inquiry by the late Professor Phillips, who asks, why is the drying up of the wells and springs an indication of coming disaster?

The author then considers the hydro-geological condition of the underground waters. He points to the well-known fact, that on the surface of volcanoes the whole of the rainfall disappears at once, and shows that when the mountain is at rest, the underground water must behave as in ordinary sedimentary strata. Therefore, the water will remain stored in the body of the mountain, in the interstices of the rocks and scoriæ, and in the many empty lava-tunnels and cavities. The level of this water will rise with the height of the mountain, and he estimates that it has at times reached in Etna a height of 5,000 to 6,000 feet, while the permanent level of the springs at the base of the mountain seems to be at about 2,000 feet. The water does not, however, form one common reservoir, but is divided into a number of independent levels by the irregular distribution of the scoriæ, lava, &c. These beds are traversed by vertical dykes running radially from the crater, so that, as they generally admit of the passage of water, the dykes serve as conduits to carry the water to the central duct.

Little is known of the sedimentary strata on which volcanoes stand.

In Naples, however, an artesian well found them under the volcanic materials in usual succession, and with several water-bearing beds, from one of which, at a depth of 1,524 feet, a spring of water rose to the surface with a discharge of 440 gallons per minute. When in a state of rest, the surplus underground waters escape in the ordinary way by springs on the surface, or when the strata crop out in the sea, they then form submarine springs.

During an eruption, these conditions are completely changed. The ascending lava, as it crashes through the solid plug formed during a lengthened period of repose, comes in contact with the water lodged around or may be in the duct, which is at once flashed into steam, and gives rise to explosions more or less violent. These explosions rend the mountain, and fresh fissures are formed which further serve to carry the water to the duct from which they proceed; or they may serve as channels for the sea-water to flood the crater, when, as in the case of Coseguina and Krakatoa, the volcano is near the sea-level. As the eruption continues, the water stores immediately around the duct become exhausted, and then the water lodged in the more distant parts of the mountain rushes in to supply the void, and the explosions are violent and prolonged according to the available volume of water in the volcanic beds. When this store is exhausted, the same process will go on with the underlying water-bearing sedimentary strata traversed by the volcanic duct.

The author gives diagrams showing the position of the water-levels *before*, *during*, and *after* eruption; and describes the manner in which, if the strata surrounding the duct and below the sea-level become exhausted, the efflux of the fresh water which passed out to sea through the permeable beds, when the inland waters stood at their normal height above the sea-level, these same beds will in their turn serve as channels for the sea water to restore the lowered water-level inland. Thus, the excurrent channels which carried the land waters into the sea-bed, and there formed, as they often do off the coasts of the Mediterranean, powerful fresh-water springs, now serve as channels for an in-current stream of sea water, which like the fresh waters it replaces, passes into the volcanic duct. This agrees with the fact that diatomaceous fresh-water remains are common in many eruptions, and marine remains in others; also, that the products of decomposition of sea water are so abundant during and at the close of eruptions. With the fall of the water-levels, the available supply of water becomes exhausted, or the channels of communication impeded, and this continues until, with the ceasing of the extravasation of the lava, the eruption comes to an end.

The author then explains the way in which the water may gain access to the lava in the duct, notwithstanding heat and pressure.

This he considers to be dependent upon the difference between the statical and the kinetical pressure of the column of lava on the sides of the duct. In the change from the one state to the other, when the lava begins to flow, and its lateral pressure is lessened, the equilibrium with the surrounding elastic high pressure vapour becomes destroyed, and the vapour forces its way into the ascending lava. As this proceeds, the heated water further from the duct, and held back by the pressure of the vapour, flashes into steam to supply its place. If that water should be lodged in the joints of the surrounding rock, blocks of it will also be blown off, driven into, and ejected with, the ascending lava, as have been the blocks in Somma and of other volcanoes.

It is the double action thus established between the inland- and sea-waters that has probably prolonged the activity of the existing volcanoes settled in ocean centres, or along coast lines, while the great inland volcanic areas of Auvergne, the Eifel, Central Asia, &c., have become dormant or extinct.

But if water only plays a secondary part in volcanic eruptions, to what is the motive power which causes the extravasation of the lava to be attributed? This involves questions connected with the solidity of the globe far more hypothetical and difficult of proof. The author first takes into consideration the probable thickness of the earth's crust from a geological point of view, and shows, that although the present stability of the earth's surface renders it evident that the hypothesis of a thin crust resting on a fluid nucleus is untenable, it is equally difficult to reconcile certain geological phenomena with a globe solid throughout, or even with a very thick crust. The geological phenomena on which he relies in proof of a crust of small thickness, are:—1. Its flexibility as exhibited down to the most recent mountain uplifts, and in the elevation of continental areas. 2. The increase of temperature with depth. 3. The volcanic phenomena of the present day, and the out-welling of the vast sheets of trappean rocks during late geological periods.

He considers that the squeezing and doubling up of the strata in mountain chains—as, for example, the 200 miles of originally horizontal strata in the Alps, crushed into a space of 130 miles (and in some cases the compression is still greater)—can only be accounted for on the assumption of a thin crust resting on a yielding substratum, for the strata have bent as only a free surface plate could to the deformation caused by lateral pressure. If the globe were solid, or the crust of great thickness, there would have been *crushing* and *fracture*, but not *corrugations*. Looking at the dimensions of these folds, it is evident also that the plate could not be of any great thickness. This in connexion with the increase of heat with depth, and the rise of the molten lava through volcanic ducts, which, if too

long, would allow the lava to consolidate, leads the author to believe that the outer solid crust may be less even than 20 miles thick.

That the crust does possess great mobility is shown by the fact that since the glacial period, there have been movements of continental upheaval—to at least the extent of 1,500 to 1,800 feet—that within more recent times they have extended to the height of 300 to 400 feet or more, and they have not yet entirely ceased.

With regard to the suggestion of the late Professor Hopkins that the lava lies in molten lakes at various depths beneath the surface, the author finds it difficult to conceive their isolation as separate and independent local igneous centres, in presence of the large areas occupied by modern and by recently extinct volcanoes. But the chief objection is, that if such lakes existed they would tend to depletion, and as they could not be replenished from surrounding areas, the surface above would cave in and become depressed, whereas areas of volcanic activity are usually areas of elevation, and the great basaltic out-wellings of Colorado and Utah, instead of being accompanied by depression, form tracts raised 5,000 to 12,000 feet above the sea-level.

These slow secular upheavals and depressions, this domed elevation of great volcanic areas, the author thinks most compatible with the movement of a thin crust on a slowly yielding viscid body or layer, also of no great thickness, and wrapping round a solid nucleus. The viscid magma is thus compressed between the two solids, and while yielding in places to compression, it, as a consequence of its narrow limits, expands in like proportion in conterminous areas. As an example, he instances the imposing slow movements of elevation which have so long been going on along almost all the land bordering the shores of the Polar Seas, and to the areas of depression which so often further south subtend the upheaved districts.

With respect to the primary cause of these changes and of the extravasation of lava, the author sees no hypothesis which meets all the conditions of the case so well as the old hypothesis of secular refrigeration and contraction of a heated globe with a solid crust,—not as originally held, with a fluid nucleus, but with the modifications which he has named, and with a *quasi rigidity* compatible with the conclusions of the eminent physicists who have investigated this part of the problem. Although the loss of terrestrial heat by radiation is now exceedingly small, so also is the contraction needed for the quantity of lava ejected. Cordier long since calculated that supposing five volcanic eruptions to take place annually, it would require a century to shorten the radius of the earth to the extent of 1 mm. or about $\frac{1}{25}$ inch.

The author, therefore, concludes that while the extravasation of the lava is due to the latter cause, the presence of vapour is due alone to

the surface and underground waters with which it comes into contact as it rises through the volcanic duct, the violence of the eruption being in exact proportion to the quantity which so gains access.

IV. "On the Fibrin-yielding Constituents of the Blood Plasma." By L. C. Wooldridge, M.B., D.Sc., Demonstrator of Physiology in Guy's Hospital. From the Laboratory of the Brown Institution. Communicated by Professor Michael Foster, Sec. R.S. Received March 26, 1885.

There is no doubt that from every variety of blood plasma a proteid body may be isolated, which can by appropriate means be converted into fibrin. This body, which is known as fibrinogen, has been more especially studied by Hammarsten. This observer has shown that fibrinogen possesses characters which clearly distinguish it from the other supposed factor in coagulation, viz., paraglobulin, and also that solutions of fibrinogen will, when treated with fibrin ferment, give rise to fibrin. The only objection possible to Hammarsten's experiments is that the body which he isolated has either previously to or during the process of isolation undergone alteration. That it is in fact not the same body which is present in the circulating blood, but that it is, so to say, a sort of nascent fibrin. My observations bear on this point.

Peptone plasma is obtained by injecting a solution of peptone into the veins of an animal, and bleeding it directly afterwards. The blood does not clot, and by means of the centrifuge the plasma is obtained. The injection of peptone produces this effect by preventing the interaction of leucocytes and plasma which normally takes place in shed blood.* By repeated centrifugalising, the whole of the corpuscular elements can be removed from this plasma, and the pure plasma thus obtained can be made to clot in the most complete manner, giving rise to a large quantity of fibrin, and this without the addition of any further proteid body, so that the plasma must contain dissolved in it the mother substance or substances of fibrin.

In a note presented to the Society a few weeks ago, I described a new constituent of the plasma which gives rise to fibrin and to other bodies concerned in coagulation. I need not refer at length in the present paper to this new substance. It is separable from the plasma by cooling the latter, and after its removal the plasma still yields a large quantity of fibrin, and from this plasma, by Hammersten's method, a body can be isolated, agreeing in all particulars with Hammersten's fibrinogen, and clotting readily with fibrin ferment.

* Wooldridge: "Zur Gerinnung des Blutes," "Archiv für Physiol.," Jahrg. 1883, p. 389.